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For: **MULTIPLE WAVELENGTH LASER SOURCE**

The Commissioner of Patents and Trademarks
Washington, D.C., 20231, U.S.A.

April 30, 2001

Dear Sir:

Enclosed please find a certified copy of the priority document in support of the above-identified patent application.

Respectfully,

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This is to certify that the documents attached hereto and identified below are true copies of the documents on file in the Patent Office.

Specification and Drawings, as originally filed, with Application for Patent Serial No: **2,302,105** on March 24, 2000, by **AHMAD K. ATIEH**, for "Multiple Wavelength Laser Source".

Agent certificateur/Certifying Officer

March 19, 2001

Date

Canada

(CIPO 68)
01-12-00

OPIC CIPO

MULTIPLE WAVELENGTH LASER SOURCE

DESCRIPTION

TECHNICAL FIELD:

This invention relates to laser sources suitable for wavelength-division multiplexed optical communications systems.

BACKGROUND ART:

Recently developed Wavelength Division Multiplexed (WDM) and Dense Wavelength Division Multiplexed (DWDM) optical transmission systems require light at multiple wavelengths. Hitherto, this has been achieved using several single wavelength laser sources in parallel.

An example of a laser source which would generate such a single wavelength was disclosed by C.R.O. Cochlain and R.J. Mears in an article entitled "Broadband tunable single frequency dialled pumped erbium-doped fiber laser", Electronics Letters, vol. 28, no. 2, p. 124 (1992). Their laser comprises a loop mirror formed by a 3-dB coupler and an erbium-doped fiber having its ends connected to respective ports of the coupler by an isolator and a wavelength selective coupler (WSC), the latter coupling energy from a pump into the erbium-doped fiber. A polarisation controller between the WSC and the 3-dB coupler controls the passage of amplified spontaneous emission (ASE) into the coupler, while the isolator blocks the ASE from reaching the other port of the coupler. A third port of the 3-dB coupler is connected to a grating by way of a second polarization controller while the fourth port delivers the output signal. Rotation of the grating selects the individual wavelength at which the laser will lase. The ASE will be reflected by the grating back through the coupler and will pass, via the isolator, around the loop to appear at the output of the laser. The grating reflects almost 100 per cent of the light reaching it, so the output signal can be extracted from only the one point in the system, namely from the fourth port of the coupler. The device cannot readily be adapted for multiple wavelength use and so the common practice would be to use a number of these devices, each one tuned to a different wavelength, to provide the multiple wavelengths required for WDM or DWDM. This approach

is expensive, however, because it requires much duplication of components.

The present invention seeks to overcome these disadvantages and to this end provides a laser source capable of operating at multiple wavelengths.

DISCLOSURE OF INVENTION:

According to the present invention, a multiple wavelength laser source comprises a loop mirror formed by a loop of active fiber and a 3-dB coupler, the fiber being connected between two ports of the coupler, pump means for injecting pump energy into the active fiber, and a plurality of wavelength-selective reflection devices coupled to at least a third port of the coupler, each reflection device for reflecting into the fiber loop a first portion, having the selected wavelength, of amplified spontaneous emission produced by the active fiber, and directing a second portion to an output port, the selected wavelengths of the plurality of reflection devices being different.

Each reflection device will reflect back into the loop mirror ASE at its own particular selected wavelength. Consequently, the laser source will lase at each of the different wavelengths of the plurality of reflection devices, thereby producing output light at a plurality of different wavelengths which can be used for WDM or DWDM.

One or more of the reflection devices may transmit the second portion to the output port. Additionally or alternatively, one or more of the reflection devices may reflect the second portion to the output port, conveniently by way of an additional 3-dB coupler.

In one preferred embodiment of the invention, the plurality of reflection devices are in series between the coupler and the output port and each reflects the first portion back to the loop mirror and transmits the second portion to the output port.

Preferably, the first and second portions each comprise about 50 per cent.

In an alternative preferred embodiment, the plurality of reflection devices are each coupled to the corresponding port of the 3-dB coupler by a second 3-dB coupler, an output port of the coupler being coupled to an output port of the laser, each reflection device reflecting both the first portion and the second

portion to the second coupler and the second coupler directing the first portion to the loop mirror and the second portion to the associated output port. One or more of the reflection devices coupled to the additional coupler may transmit a third portion of the ASE to an associated second output port.

The laser source may comprise a plurality of attenuators, each between the fiber loop and one of the reflection devices. The attenuators may be used to adjust the amount of ASE reflected and hence control the amplitude of the laser output signal at the corresponding selected wavelength.

The number of reflection devices coupled to each port of the 3-dB coupler need not be the same.

BRIEF DESCRIPTION OF THE DRAWINGS:

Figure 1 illustrates, as a first embodiment of the invention, a laser source having a plurality of gratings in series;

Figure 2 illustrates, as a second embodiment of the invention, a laser source having a plurality of gratings in parallel;

Figure 3 illustrates the spectrum of the laser output from a first four output ports of the laser source of Figure 2; and

Figure 4 illustrates the spectrum of the laser output from fifth and sixth output ports of the laser source of Figure 2.

BEST MODE(S) FOR CARRYING OUT THE INVENTION:

In the drawings, identical or corresponding items in the different Figures have the same reference number.

Referring first to Figure 1, a laser source comprises a loop mirror formed by a 3-dB fiber coupler 10 having four ports identified in Figure 1 as A, B, C and D, and a loop of active fiber 12, preferably erbium-doped, with its ends connected to ports C and D, respectively, each by a respective one of a pair of identical pump means comprising wavelength-selective couplers 14 and 16 connected to pump sources 18 and 20, respectively.

Port A of the coupler 10 is coupled to a first output port $P1_{OUT}$ by a plurality of fiber gratings 22A, 24A, and so on, having characteristic wavelengths λ_1, λ_3, ..., respectively, in series and port B of the coupler 10 is

coupled to a second output port $P2_{OUT}$ by a second plurality of fiber gratings 22B, 24B, and so on, having characteristic wavelengths $\lambda_2, \lambda_4, \ldots$, respectively, in series. Each of the fiber gratings 22A, 24A, 22B, 24B, and so on reflects about one half of the light incident upon it at the selected wavelength and transmits the remainder.

In operation, the pump energy from pump sources 18 and 20 produces amplified spontaneous emission in the EDF 12. Assuming symmetry, 50 per cent of the ASE will appear at each of the ports C and D of the 3-dB coupler 10 and be coupled to ports A and B. Grating 22A will reflect 50 per cent of the light leaving port A so that it re-enters the loop mirror and transmit the remainder to grating 24A which, in a similar manner, will reflect 50 per cent of the ASE at its own selected wavelength and transmit the remainder. Any other gratings in series with the first output port $P1_{OUT}$ will operate in a similar manner. Once lasing conditions have been established, the first output signal appearing at output port $P1_{OUT}$ will comprise the wavelengths λ_1, λ_2, and so on of the gratings 22A, 24A, and so on.

The ASE light leaving port B of the 3-dB coupler 10 will be reflected and transmitted in a similar manner by the fiber gratings 22B, 24B, and so on in series with second output port $P2_{OUT}$ so that the light leaving output port $P2_{OUT}$ comprises the wavelengths λ_2, λ_4, and so on of gratings 22B, 24B and so on.

For most WDM or DWDM applications, it is desirable for the amplitude of the output signal to be the same at each wavelength. Consequently, an attenuator may be provided in series with each of the gratings 22A, 24A, 22B, 24B and so on and used to adjust the amount of light reflected by that grating, and hence the amplitude of the output light at the corresponding wavelength.

The laser source illustrated in Figure 2 also has a loop mirror formed by a 3-dB fiber coupler 10 having four ports A, B, C and D, and a loop of active fiber 12, preferably erbium-doped, with its ends connected to ports C and D, respectively, each by a respective one of a pair of identical pump means comprising wavelength-selective couplers 14 and 16 connected to pump sources 18 and 20, respectively. It differs from that shown in Figure 1 because the fiber gratings are not connected in series to the port A of fiber coupler 10. Inst ad, the gratings effectively are in parallel. Thus, gratings 22A

and 22B are connected to ports A and B of a second 3-dB c upler 30 by way of attenuators 32A and 32B, respectively, while gratings 24A and 24B are connected to ports A and B of a third 3-dB coupler 34 by way of attenuators 36A and 36B, respectively. The transmissive ports of the gratings 22A, 22B, 24A and 24B are connected to four output ports $P1_{OUT}$, $P2_{OUT}$, $P3_{OUT}$ and $P4_{OUT}$, respectively. Ports D of the couplers 30 and 34 are connected to ports A and B, respectively, of the 3-dB coupler 10 and ports C of the couplers 30 and 34 are connected to fifth and sixth output ports $P5_{OUT}$ and $P6_{OUT}$, respectively.

In operation, the ASE leaving the coupler 10 will be split again by couplers 30 and 34 before reaching the gratings 22A, 22B, 24A and 24B. Each of these gratings will reflect about 50 per cent of the ASE at its own selected wavelength and transmit the remainder, as before. Consequently, when lasing conditions have been established, the light appearing at ports $P1_{OUT}$, $P2_{OUT}$, $P3_{OUT}$ and $P4_{OUT}$ will have wavelengths λ_1, λ_2, λ_3 and λ_4, respectively, as illustrated in Figure 3.

The light leaving the output ports $P5_{OUT}$ and $P6_{OUT}$, respectively, will have been reflected by the gratings and will have passed through the attenuators again, as compared with the light leaving the first four ports $P1_{OUT}$, $P2_{OUT}$, $P3_{OUT}$ and $P4_{OUT}$. Consequently, it will have a better signal-to-noise ratio, as illustrated in Figure 4.

It should be appreciated that, if only two wavelengths were needed, one of the couplers 30 and 34, and its associated pair of gratings, could be omitted. Conversely, additional wavelengths could be obtained by adding more couplers and pairs of gratings, in a tree-like configuration. It is also envisaged that the embodiment of Figures 1 and 2 could be combined, with some of the parallel branches of the laser source having a series of gratings.

The attenuators 32A, 32B, 36A and 36B allow the amplitude of the light at each wavelength to be adjusted so that, if desired, they are equal.

Although, in the above-described laser sources, the gratings each reflect about 50 per cent of the selected wavelength light, other proportions could be used.

INDUSTRIAL APPLICABILITY

An advantage of embodiments of the invention is that a multiplicity of wavelengths can be provided using a single active-fiber loop mirror and a grating for each wavelength. Also, the number of wavelengths can be increased simply by adding more fiber gratings, and perhaps increasing the pump energy, as appropriate.

CLAIMS:

1. A multiple wavelength laser source comprising a loop mirror formed by a loop of active fiber and a 3-dB coupler, the fiber being connected between two ports of the coupler, pump means for injecting pump energy into the active fiber, and a plurality of wavelength-selective reflection devices coupled to at least a third port of the coupler, each reflection device for reflecting into the fiber loop a first portion, having the selected wavelength, of amplified spontaneous emission produced by the active fiber, and directing a second portion to an output port, the selected wavelengths of the plurality of reflection devices being different.

2. A laser source according to claim 1, wherein the plurality of reflection devices are in series between the coupler and the output port and each reflection device transmits the corresponding second portion to the output port.

3. A laser source according to claim 1, further comprising an attenuator between the plurality of reflection devices and said third port.

4. A laser source according to claim 1, 2 or 3, wherein a second plurality of reflection devices are connected between a fourth port of the 3-dB coupler and an additional output port in a configuration similar to that of the first plurality of reflection devices.

5. A laser source according to claim 1, wherein the plurality of reflection devices comprise first and second reflection devices connected between first and second ports of a second coupler and first and second output ports of the laser source, respectively, a third port of the second coupler being connected to the first port of the first coupler.

6. A laser source according to claim 5, wherein a fourth port of the second coupler is connected to a third output port of the laser source.

7. A laser source according to claim 5, comprising third and fourth reflecti n devices connected between first and second ports of a third coupler and third and fourth output ports, respectively, of the laser source, a third port of the third coupler being connected to the second port of the first coupler.

8. A laser source according to claim 7, wherein a fourth port of the second coupler is connected to a third output port of the laser source and a fourth port of the third coupler is connected to a fourth output port of the laser source.

9. A laser source according to any of claims 5 to 8, further comprising an adjustable attenuator between each grating and the associated coupler.

10. A laser source according to claim 1, wherein the first and second portions each comprise about 50 per cent.

11. A laser source according to claim 5, further comprising at least one additional reflection device in series with either of the first and second reflection devices.

12. A laser source according to claim 7, further comprising at least one additional reflection device in series with either of the third and fourth reflection devices.

ABSTRACT OF THE DISCLOSURE

A multiple wavelength laser source comprises a loop mirror formed by a loop of active fiber and a 3-dB coupler, the fiber being connected between two ports of the coupler, two pump means for injecting pump energy into the active fiber so as to propagate in opposite directions therein, and a plurality of wavelength-selective reflection devices, e.g. gratings, coupled to at least one of the other ports of the coupler. Each grating reflects back into the loop light at a certain wavelength and transmits light of other wavelengths the selected wavelength, and transmits a second portion to an output port. The selected wavelengths of the plurality of reflection devices are different. The plurality of reflection devices may be in series between the coupler and the output port, or in parallel, each coupled to the corresponding port of the 3-dB coupler by a second coupler. Preferably, the first and second portions each comprise about 50 per cent.

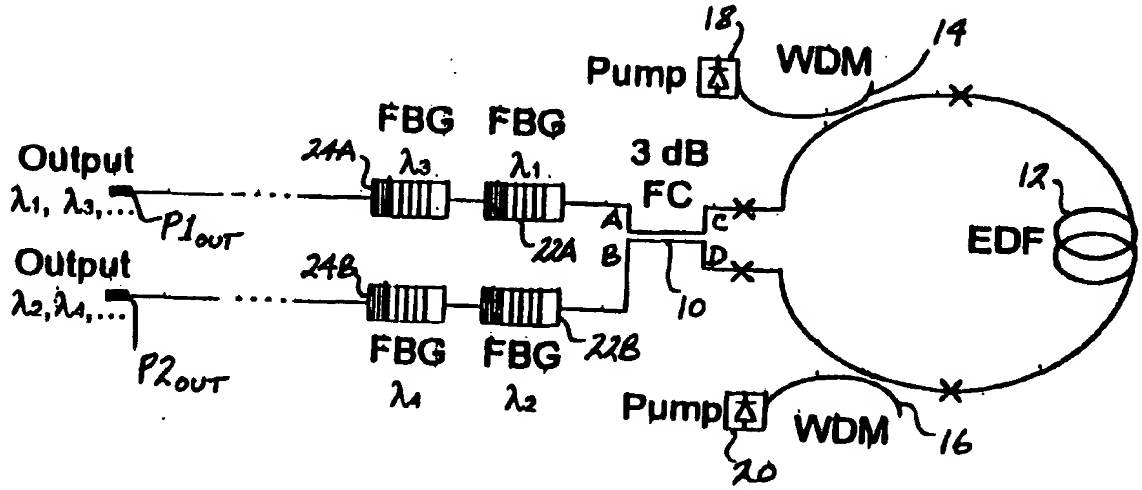

FIG. 1

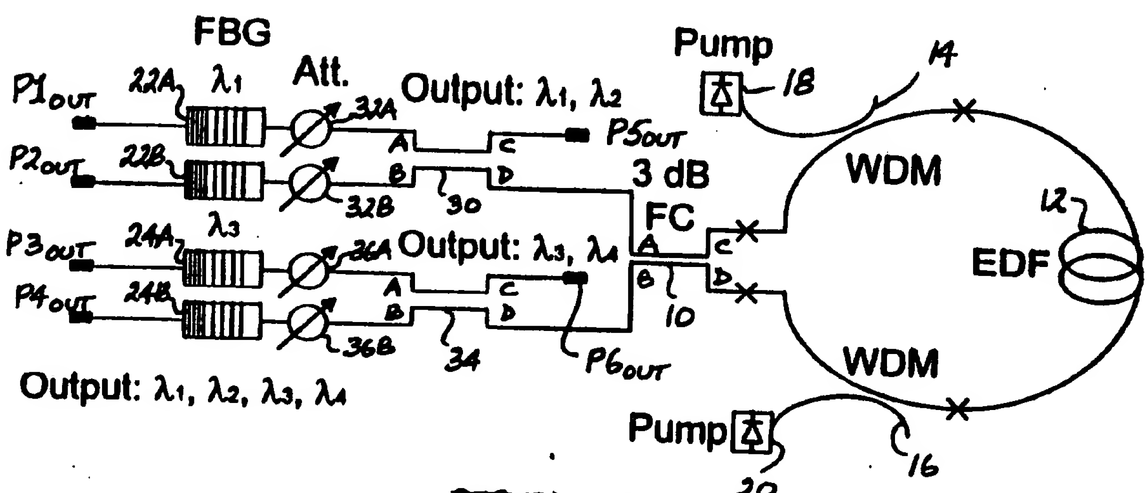

FIG. 2

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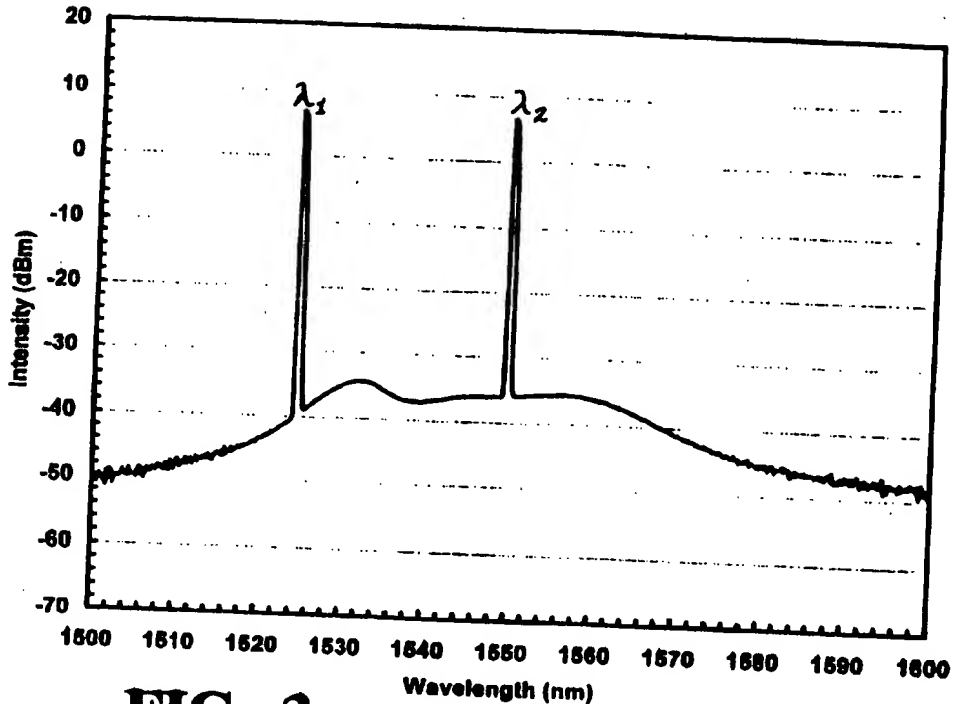

FIG. 3

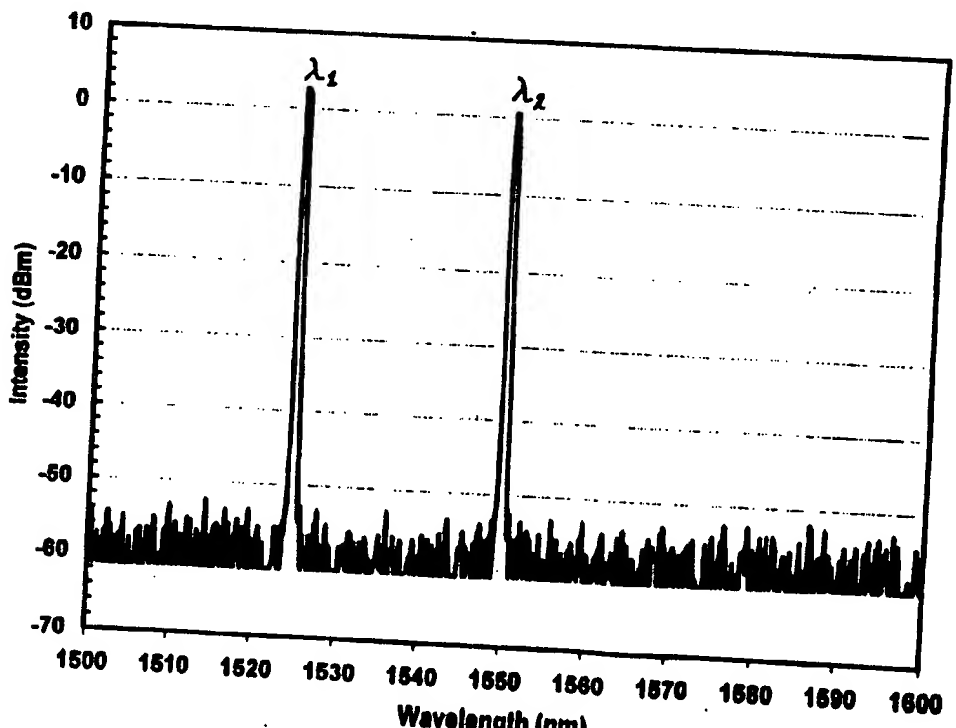

FIG. 4

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